

## **LUMEN-MEASURING DEVICES AND METHOD**

### **FIELD OF THE INVENTION**

The present invention relates to measurement devices and methods and more particularly, to devices and methods of measuring  
5 the internal diameter of a lumen of a patient and the dimensions of luminal imperfection.

### **BACKGROUND OF THE INVENTION**

Physicians involved in therapy in general and interventional cardiology and interventional radiology in particular have been  
10 attempting to find a way to deal with occluded (so called "stenotic") coronary arteries (among other blood vessels, various tubular conduits and similar structures). Additionally, the vessel diameter, as often measured using electronic calipers ('imaging' mode), and the frequency shift ('Doppler' mode) are of prime importance in  
15 determining the mean flow rate through a vessel and both must be accurately known. Unfortunately, methods of obtaining essential luminal dimensions have diverged based on inquiry; the physicians interested in interventional treatment of stenosis have approached the problem differently than those interested in determining mean  
20 flow rate through a vessel.

Interventional radiologists interested in treatment of stenosis have focused attention principally on the topology of the stenosis almost to the exclusion of other important factors. Of principal importance is the identification of stent length as a risk factor for  
25 restenosis. The usual method of choosing stent size relies on visual estimation from the angiogram. Like many practitioners interested in

this area the goal has been to assess the value of an objective means of determining stent length. In one instance, a calibrated guide wire (ATW Marker wire; Cordis) is used as a measurement tool. J.P. Reilly et al. *Use of ATW Marker Wire to Guide Choice of Stent Length*, Am J  
5 *Cardiol* 2001; 88 (suppl 5A).

The theory behind this and other studies is that choice of appropriate endoluminal revascularization device (e.g., balloon angioplasty, atherectomy, laser recanalization, stents, etc) is a function of stenosis topology. Though excessive length of endoluminal  
10 revascularization devices can lead to migration and restenosis, a principal limitation of this analysis is that there are equally important risk factors associated with vessel diameter. Many practitioners pay more care in determining appropriate stent length than expanded stent diameter. As a rule of thumb, physicians generally employ a  
15 stent that is one to two sizes larger than the estimated lumen diameter. This practice in and of itself can lead to tissue granulation and further vessel damage.

Practitioners interested in hemodynamics or patency of vessels, defined as continued flow through the treated segment, not  
20 necessarily the absence of recurrent stenosis, use alternative tools to measure lumen diameter for purposes of determining the extent of flow there through. Most frequently, imaging tests such as CT Scans are used to assist with dimensional calculations. As a result, no apparatus has been developed that allows for accurate in situ  
25 measurement of treated or target tissue for purposes of evaluating patency and/or providing interventional prosthesis.

Therefore, there is an existing need for an accurate method of measuring both stenosis topography as well as luminal dimensions so that the precise interventional prosthesis may be employed. In

particular, there is a need for a single device that can measure the width and height of a stenosis while also measuring the diameter of lumen at both healthy and stenotic regions.

#### **SUMMARY OF EXEMPLARY EMBODIMENTS**

5        It is a principal object in accordance with the present invention to provide a device capable of measuring the topology of a stenosis. In the furtherance of this and other objectives, a preferred embodiment of the present invention provides a measuring means that is disposable about, distal and proximal a stenosis for measuring  
10    the dimensions of the tissue in those locations.

      Yet another objective in accordance with a preferred embodiment of the present invention is to provide a device that is suitable for measuring the working diameter of both healthy and diseased lumen for purposes of accurately determining the  
15    dimensions of an appropriate interventional prosthesis.

      Still another objective of a preferred embodiment in accordance with the present invention is to provide a lumen measuring device and method that allows the user to calculate the exact length and diameter of a suitable interventional prosthesis as  
20    well as the height and length of stenosis during the same exploratory procedure.

      It is another objective in accordance with the present invention to provide a lumen-measuring device configured to be introduced into the working channel of a suitable anatomically  
25    correct optical scope. In the furtherance of this and other objectives, and provided by way of non limiting example only, a device in accordance with the present invention that is used for nonvascular indications in general and pulmonary indications in particular may be

suitably configured for use in the working channel of a bronchoscope. It is envisioned that the optical instrument chosen will be a function of the general vascular/nonvascular decision, anatomical location, and physician preference.

- 5 Further objectives, features and advantages of the invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is an aerial perspective view of an exemplary lumen-measuring delivery device in accordance with the present invention;

FIG. 2 is a side cross sectional view of an exemplary lumen delivery device of FIG. 1, along lines 2—2;

FIG. 3 is a side perspective view of the lumen-measuring device of FIG. 1, showing a measurement indicator through the exterior lumen;

FIG. 4 is a bottom cross sectional view of the lumen-measuring device of FIG. 3, along lines 4—4;

FIG. 5 is an aerial perspective view of an exemplary lumen-measuring delivery device in accordance with the present invention, showing the measurement assembly distally extended;

FIG. 6 is a side cross sectional view of an exemplary lumen delivery device of FIG. 5, along lines 6—6;

FIG. 7 is a side perspective view of the lumen-measuring device of FIG. 5, showing a measurement indicator through the exterior lumen;

FIG. 8 is a bottom cross sectional view of the lumen-measuring device of FIG. 7, along lines 8—8;

FIG. 9 is a cross sectional view of the legs of the measurement assembly in a closed configuration inside the exterior conduit;

FIG. 10 is a perspective view of the measurement assembly showing the legs in an open configuration, as shown along lines 10—10 of FIG. 6;

FIG. 11 is a cross sectional view of the distal region of the exterior conduit showing how the detent or lip of the exterior conduit interacts with the corresponding measurement markers on the measurement assembly legs, along lines 11—11;

FIG. 12 shows a perspective view of the lumen-measuring device of FIG. 1, showing the measurement assembly in the closed configuration as viewed from the distal tip thereof;

FIG. 13 is a perspective view of the lumen-measuring device of FIG. 1, showing the measurement assembly in the open configuration as viewed from the distal tip thereof;

FIG. 14 is a side perspective view of the closed measurement configuration of the alternative lumen-measuring device embodiment of FIG. 14 showing a measurement indicator through the exterior lumen;

FIG. 15 is a bottom perspective view of the alternative lumen-measuring device of FIG. 14, showing the legs in the closed measuring configuration;

FIG. 16 is a side perspective view of an open measurement configuration of an alternative lumen-measuring device embodiment showing a measurement indicator through the exterior lumen;

FIG. 17 is a bottom perspective view of the alternative lumen-measuring device of FIG. 14, showing the legs in the open measuring configuration;

FIG. 18 is a side perspective view of the measurement assembly of the alternative lumen-measuring device of FIG. 14, showing the legs in the open measuring configuration;

FIG. 19 is a side perspective view of an exemplary lumen-measuring device, wherein the measurement assembly comprises a  
5 dilation balloon, a diameter measurement balloon and measurement markers.

FIG. 20 is a cross sectional view of the lumen-measuring device of FIG. 19, showing the internal conduits, that feed the respective  
10 balloons, along lines 20—20;

FIG. 21 is a perspective view of the measuring portion of the lumen-measuring device of FIG. 19, showing the measurement markers on the dilation balloon in the uninflated configuration;

FIG. 22 is a side view of the measuring portion of the lumen-measuring device of FIG. 19, showing the measurement markers on  
15 the dilation balloon in the uninflated;

FIG. 23 is a perspective view of the measuring portion of the lumen-measuring device of FIG. 19, showing the measurement markers on the diameter measurement balloon in the inflated configuration;

FIG. 24 is a side view of the measuring portion of the lumen-measuring device of FIG. 19, showing the measurement markers on  
20 the diameter measurement balloon in the inflated;

FIG. 25 is a perspective view of the measuring portion of the lumen-measuring device of FIG. 19, showing the measurement markers  
25 on the dilation and diameter measurement balloons in the inflated configuration;

FIG. 26 is a side view of the measuring portion of the lumen-measuring device of FIG. 19, showing the measurement markers on the dilation and diameter measurement balloons in the inflated;

FIG. 27 is a perspective view of an exemplary lumen-measuring device of FIG. 19, indicated for nonvascular lumen, showing the lumen-measuring device disposed within the working channel of a bronchoscope, wherein the measurement assembly comprises a dilation balloon about a stenosis, a diameter measurement balloon which is in the inflated configuration and measurement markers;

FIG. 28 is a side view of an exemplary lumen-measuring device of FIG. 19, indicated for nonvascular lumen, showing the lumen-measuring device disposed within the working channel of a bronchoscope, wherein the measurement assembly comprises a dilation balloon about a stenosis, a diameter measurement balloon which is in the inflated configuration and measurement markers;

FIG. 29 is a cross sectional view of the co-extruded conduits, of FIG. 20, showing an inflation channel along lines 29—29; and

FIG. 30 is a side cross sectional view of the co-extruded conduits, of FIG. 20, showing an inflation channel along lines 30—30.

#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

A preferred embodiment in accordance with the present invention provides a lumen measuring device and method that allows the user to calculate the exact length and diameter of a suitable interventional prosthesis as well as the height and length of stenosis during the same exploratory procedure. In the furtherance of this and other objectives, an exemplary device is capable of measuring the topology of a stenosis by providing a measuring means that is disposable about, distal and proximal a stenosis for measuring the dimensions of the tissue in those locations. Moreover, the device is suitable for measuring the working diameter of both healthy and

diseased lumen for purposes of accurately determining the dimensions of an appropriate interventional prosthesis.

The device is capable of being introduced into the working channel of a suitable anatomically correct optical scope. For example, a device in accordance with the present invention that is used for nonvascular indications in general and pulmonary indications in particular may be suitably configured for use in the working channel of a bronchoscope. As discussed above, the optical instrument chosen will be a function of the general vascular/nonvascular decision, anatomical location, and physician preference.

Now making specific reference to the Figures where like numerals refers to like components, a lumen-measuring device is provided to give more accurate lumen dimensional information for purposes of interventional treatment. In particular, a lumen-measuring device 100 is provided generally in FIGS. 1-13.

In a preferred embodiment, the lumen-measuring device 100 comprises a plurality of conduits longitudinally extending between proximal and distal ends, namely exterior 130 and interior 180 conduits, the exterior conduit 130 is coupled with a handle 220 at the proximal end and a measurement assembly 240 at the distal end. The handle 220 and the measurement assembly 240 being operatively connected with one another via the interior conduit 180 at the interior conduit's proximal 190 and distal ends 200, respectively. The interior conduit 180 also has a depth marking mechanism 210 visible through the proximal region of the exterior conduit 140. The handle 220 provides a trigger mechanism 230 that allows the user to place the measurement assembly 240 in an open or closed configuration by pushing or pulling the trigger mechanism 230. The trigger 230 is preferably a slide-gauged mechanism but may be any number of



alternative guiding systems known in the art. In the slide gauge embodiment, when the trigger mechanism 230 is pushed in a distal direction with respect to the handle 220, the interior conduit 180 urges the measurement assembly 240 distal the exterior conduit 130 causing the measurement assembly 240 to open. Retracting the trigger mechanism 230 in a proximal direction with respect to the handle 220 closes the measurement assembly 230.

The measurement assembly 230 comprises at least two legs 250, 300 having distal 260, 310 and proximal ends 270, 320 and inward facing 280, 330 and lumen facing 290, 340 surfaces, the legs are preferably coupled with each other at their respective proximal ends 270, 320. Distal the point at which the legs 250, 300 are coupled, the legs 250, 300 are designed to diverge from one another when unconstrained. In the furtherance of this objective, the legs 250, 300 are preferably formed of a shape memory alloy such as nitinol so that when the legs are constrained by the exterior conduit 130 they lay substantially flush with respect to one another but diverge when the exterior conduit 130 is evacuated.

Additional legs may be employed so that the topology of the lumen 570 may be assessed from varying perspectives. In a preferred embodiment, four legs are provided. Each leg is provided with measurement markers 350 that are disposed at predetermined intervals between the distal and proximal ends of each leg. Accuracy and corresponding leg dimensional measurements can be confirmed and calibrated by providing the lumen-measuring device 100 into a vessel with known interior dimensions. The legs are then urged distally until the distal ends of the legs touch the interior surface of the vessel. Since the interior dimensions of the vessel are known, it is easy to

calibrate the measuring device so that the measurement markers correspond to the known dimensions.

As an added feature to ensure accuracy, preferred embodiments of the present device provide legs that have measurement markers 350 that are carved into the legs so as to form detent or lip catches 360. Depending on the embodiment described, markers 350 and lip catches 360 may be used interchangeably as one or both may be present in the same location. The exterior conduit 130 has corresponding detents 170 or a lip 170 about the distal end 150 thereof to ensure that the legs do not overshoot the maximum lumen measurement and damage the lumen tissue. Moreover, only moderate distal force is necessary to urge the legs beyond the lip 170, however, once the proper extension has been achieved, this feature allows the measuring assembly to remain stable until the calculation has been made.

Referring now to FIGS. 14-18, in an alternative embodiment, instead of the distal ends of the legs making independent contact with the lumen surface, the distal ends are coupled together so that measurement takes place proximal the distal ends of the legs. In this embodiment, the measurement assembly takes on the configuration of a whisk, wherein the exterior diameter at the distal and proximal ends, when if fully extended, is significantly smaller relative to the measurement portion there between. However, when the measurement assembly is retracted, the legs are relaxed and reside adjacent one another so that the legs may be retracted within the exterior conduit.

In this and other related embodiments, the exterior conduit has measurement markers 160 formed thereon. Additionally, the lumen facing surfaces 280, 330 of the measurement assembly 240 legs have

measurement markers 350 and/or 360 formed thereon. As the trigger mechanism 230 is pushed distally, the measurement assembly 240 moves distal the distal end 150 of the exterior conduit 130 and begins to separate the legs of the measurement assembly 240 with respect to one another. The further the trigger mechanisms 230 is pushed in the distal directions, the further the legs open and the greater the number of measurement markings 350 and/or 360 on the measurement assembly 240 extended beyond the distal end 150 of the exterior conduit 130. In a preferred embodiment, the distal end 150 of the exterior conduit 130 have inward facing detents or lip 170 that are complementary to the measurement markers 350 and/or 360 on the measurement assembly 240. At each measurement marking 350, the detent or lip 170 may be engaged by the detent catches 360 of the measurement marker 350 to prevent overshooting the target. Once the legs have been opened until the distal ends of the legs of the measurement assembly 240 are in contact with the tissue to be measured, the user need only count the measurement markings 350 to determine the desired dimensions of the target tissue.

In order to determine the length of the target tissue, the user need only open the measurement assembly 240 just proximal and just distal the target tissue, in no particular order and note the distances between the two locations on the depth marking mechanism 210 of the interior conduit 180, which is preferably just distal the handle 220.

An alternative embodiment of the present invention, as shown specifically in FIGS. 19-30 comprises a flexible device 420 with preferably two balloons and three conduits--one conduit for each balloon and one that goes all the way through. The bottom balloon is substantially flat and round and is referred to generally as the diameter measurement balloon 480; the upper balloon is longer and

narrow and is referred to generally as the dilation balloon 430. The first conduit 520 preferably inflates the diameter measurement diameter measurement balloon 470 and the second conduit 550 inflates the dilation balloon 430. The third conduit 560, which preferably  
5 terminates at the distal end tip 540, principally serves a delivery and measurement function. In a preferred embodiment, the outermost conduit 520 has measurement markings 530 that are visible from the interior and/or the exterior thereof.

The diameter measurement balloon 470 has substantially flat  
10 distal 480 and proximal 490 surfaces, with a substantially circular edge 500 there between, resulting in a hollow pancake shaped configuration. In a preferred embodiment, the diameter measurement balloon 470 has diameter measurement marker 510 of varying colors on the proximal and/or distal surface thereof to form a  
15 target like representation. Alternatively, the dilation balloon 430 has a substantially cylindrical shape with proximal 450 and distal ends 440 coupled along the outermost conduit 520.

When the pre-sterilized device is initially installed the diameter measurement balloon 470 is compressed proximal the distal tip 540 of  
20 the outermost conduit 520 and the dilation balloon 430 is compressed about the outermost conduit 520, proximal the diameter measurement balloon 470. In this configuration, as specifically shown in FIGS. 27-28, the device is easily delivered to the target site. When used to evaluate stenotic tissue, the tip 540 is preferably positioned  
25 distal the stenosis 580 such that the diameter measurement balloon is placed just distal the stenosis. The diameter measurement balloon 470 is then inflated sufficiently to allow it to sit flush with the inner diameter of the subject lumen 570 or stenosis 580.

Through the use of visualization means, such as optical instruments like a bronchoscope 110, the topology of the stenosis 580 can be directly viewed. The diameter measurement balloon 470 is preferably designed with diameter measurement markers 510 formed  
5 on the proximal face thereof to allow the user to visually measure the extent of luminal occlusion based on the number of diameter measurement markers covered by the stenosis 580 when viewing the diameter measurement balloon 470 from a position proximal the stenosis 580. Furthermore, this allows the physician to see if the  
10 stenosis 580, or other observed occlusion, is symmetrical, etc.

Simultaneously, the physician may observe the measurement markers 460, 510 visible through the outermost conduit 520 to see the dimensions of the occlusion from end-to-end or from specific points. Additionally, the dilation balloon 430 may also be inflated to serve as  
15 an additional measurement of the working diameter of the diseased lumen 570. To this end, the dilation balloon 430 is inflated until it substantially closes the diseased portion of the lumen 570.

Based on the measurements collected from this simple and inexpensive procedure, an interventional prosthesis may be selected,  
20 if necessary, that is appropriate in length and diameter so as to prevent further damage to the target lumen while providing sufficient outward radial support.

In this and other embodiments that employ balloons, a predetermined air pressure is provided to each balloon and each  
25 balloon conduit may be configured with a pressure manometer.

The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative, and not restrictive. The scope of the invention is,

therefore, indicated by the appended claims, rather than by the foregoing description. All changes, which come within the meaning and range of equivalency of the claims, are to be embraced within their scope.